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DRL NO. 186
DRD NO. SE-2

INTERMEDIATE LOAD MODULES FOR TEST AND EVALUATION

FINAL DESIGN REPORT

DRD NO. SE-2

7 SEPTEMBER 1984

JPL CONTRACT NO. 956349

PREPARED BY

SOLAVOLT INTERNATIONAL
3646 EAST ATLANTA AVENUE
PHOENIX, ARIZONA 85040

THE JPL FLAT-PLATE SOLAR ARRAY PROJECT IS SPONSORED BY THE U.S. DEPARTMENT OF ENERGY AND FORMS PART OF THE SOLAR PHOTOVOLTIAC CONVERSION PROGRAM TO INITIATE A MAJOR EFFORT TOWARD THE DEVELOPMENT OF LOW-COST SOLAR ARRAYS. THIS WORK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY BY AGREEMENT BETWEEN NASA AND DOE.

PROJECT NO. 8701

SOLAVOLT INTERNATIONAL

(NASA-CR-175697) INTERMEDIATE LOAD MODULES FOR TEST AND EVALUATION Final Design Report (Solavolt International) 38 p HC A03/MF A01 CSCL 10A

N85-24526

Unclas

G3/44 21015

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the United States Department of Energy through an agreement with the National Aeronautics and Space Administration.

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PROJECT NO. 8701

SOLAVOLT INTERNATIONAL

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

1. INTRODUCTION

The purpose of this contract was to provide photovoltaic modules for test and qualification against the JPL Block V qualification tests as outlined in JPL 5101-161, dated February 20, 1981. Tasks involved in this effort involved the following activities.

- Delivery of 20 solar cells for use as reference cells.
- Module documentation and inspection plans specifying the 10 Group I modules delivered to JPL prior to this contract.
- A design review with JPL to review module documentation and test results from Group I modules.
- Revise module documentation and inspection plans incorporating changes to overcome any problems or deficiencies associated with the Group I modules.
- Delivery of 10 Group II modules built to revised specifications.
- Testing of Group II modules to the criteria as outlined in JPL 5101-161 Block V qualification specification.

SECTION 2

SOLAVOLT

SOLAR CELL MODULE

INTERFACE CONTROL AND ASSEMBLY DRAWINGS

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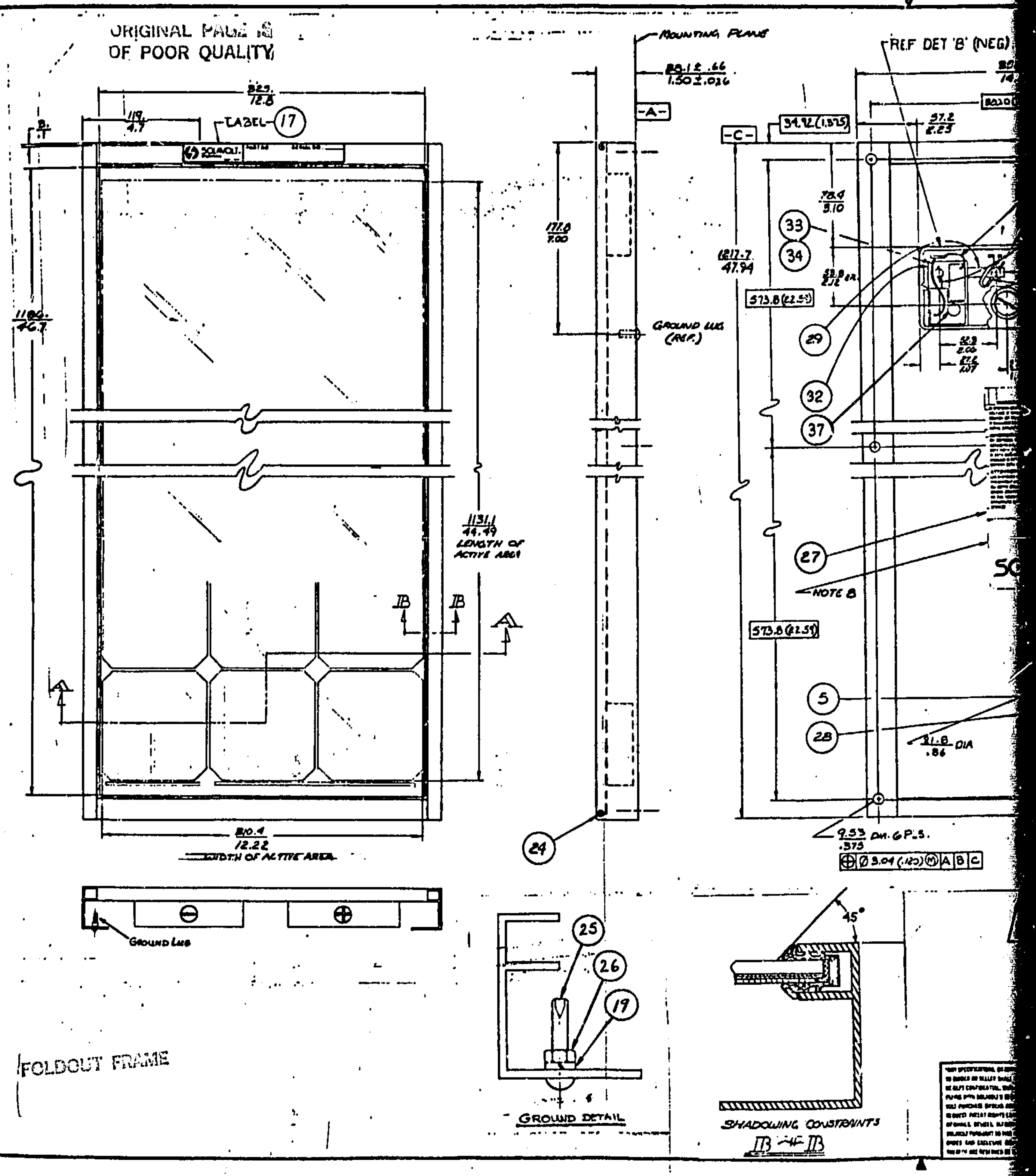

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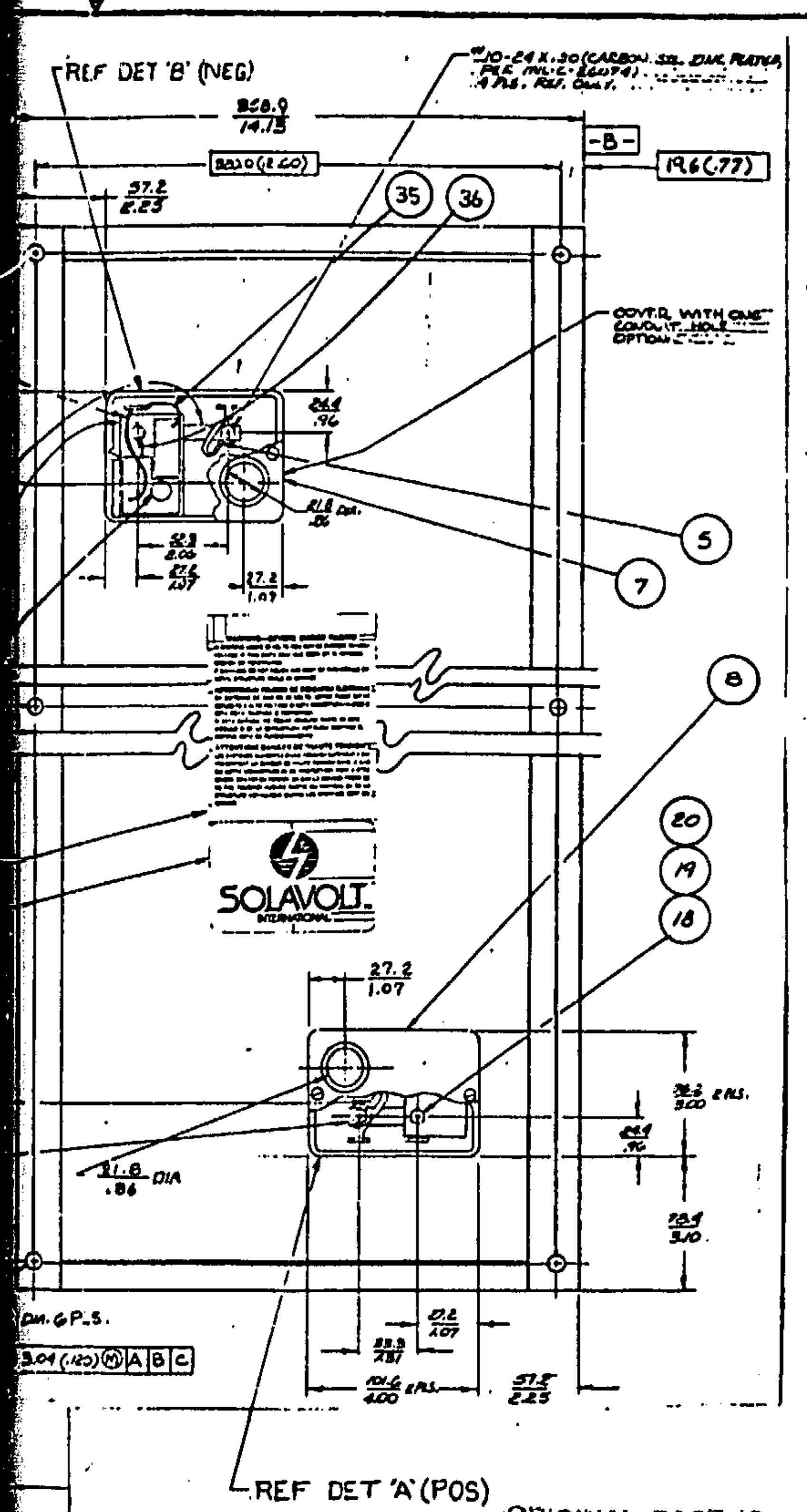
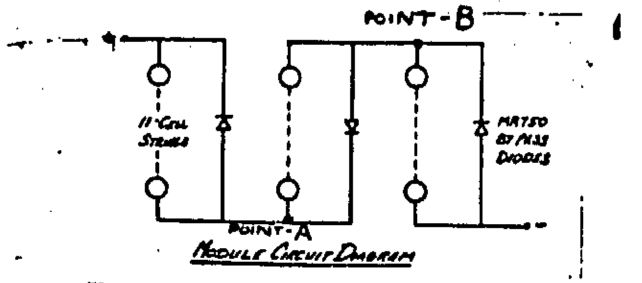


REV.	ECO NO.	CHANGE	DATE	BY	ENGR.
B		REVISED - SEE OBSOLETE ISSUE FOR DETAILS.			B.L.
C		ADD NOTE NO. 9 ADD DETAIL A + B AT J BOXES			B.L.

NOTES

1. MOUNTING PROVISION MAT'LS:
   1.1 MOUNT FLANGES ARE FABRICATED WITH ALUMINUM ALLOY TYPE 6063-T5
   1.2 CARE MUST BE TAKEN NOT TO ESTABLISH AN ELECTROGALVANIC CELL BETWEEN THE MODULE AND SUPPORT FRAMEWORK. ACCEPTABLE MOUNTING MAT'LS. INCLUDE 300 SERIES STAINLESS STEEL, NICKEL, CHROMIUM, TIN AND ZINC.
2. OUTPUT TERMINATION USER CONSTRAINTS:
   2.1 MAXIMUM J-BOX STUD TORQUE, 5 IN LBS.
   2.2 MAXIMUM J-BOX COVER SCREW TORQUE 20 IN OZS.
   2.3 MAXIMUM APPLIABLE DEAD WEIGHT TO J-BOX 3 Kg (6.6 LBS.)
   2.4 USAGE OF FLEXIBLE CONDUIT (EG PVC COATED) IS RECOMMENDED.
   2.5 ATTACHMENT OF CONDUIT AND ARRAY WIRING IS TO BE COMPLETED AFTER MODULE IS MOUNTED IN ARRAY FRAME.
3. GROUND TERMINATION USER CONSTRAINTS:
   3.1 GROUND STUD MAT'L. IS STAINLESS STEEL.
   3.2 SEE NOTE (1) FOR ACCEPTABLE INTERFACE MAT'L.
   3.3 MAXIMUM GROUND STUD TORQUE 20 IN LBS.
   3.4 GROUND WIRE IS TO BE MOUNTED FROM THE BACK SIDE AFTER MODULE IS MOUNTED IN ARRAY FRAME.
4. MAXIMUM MODULE WEIGHT: 6.0 Kg (13.6 LBS)
5. ELECTRICAL CIRCUIT:
   5.1 SERIES CELL CONNECTION.
   5.2 THREE REDUNDANT RIBBONS PER CELL.
6. TERMINATION MAT'LS.
   6.1 STUD: 304 PASSIVATED STAINLESS STEEL
   6.2 WASHERS: FLAT WASHER, BRASS, No. 230, 240, 268 PER ASTM B36 OR BRASS No. 342, 353, PER ASTM B121. EXT. TOOTH, LOCK WASHER, PHOSPHOR BRONZE No. 510 OR 524 PER ASTM B139.
   6.3 HEX NUT: BRASS (COPPER ALLOY No. 360) PER ASTM B16.
   6.4 J-BOX & COVER: POLY CARBONATE.
7. OPTIONAL J-BOX COVER:
   7.1 PARALLEL MODULE TO MODULE CONNECTIONS UTILIZE J-BOX COVER WITH TWO CONDUIT HOLES.
   7.2 SERIES MODULE TO MODULE CONNECTIONS UTILIZE J-BOX COVER WITH ONE HOLE.
8. WARNING LABEL AND LOGO LABEL TO BE LOCATED APPROXIMATELY ON CENTER OF BACK SKIN OF MODULE.
9. MODULE ELECTRICAL CHARACTERISTICS
   100 M W/CM². AM 1.5 TCELL = 25°C, 15.0 VOC
   MIN MODULE POWER = 34.7 WATTS



MODULE CIRCUIT DIAGRAM

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FOLDOUT FRAME 2

UNLESS OTHERWISE SPECIFIED: TOLERANCES: INCHES .XX ± .XXX ± MILLIMETERS .X ± .XX ± ANGULAR ±	MATERIAL: IBM CIA3B00829B
RMS ALL MACHINED SURFACES.	QTY REQ'D
FEATURE CONTROL SYMBOLS PER ANSI Y14.5.	APPLIED FINISH
BREAK ALL SHARP EDGES AND CORNERS. REMOVE BURRS.	DRAWN BY H. VanOven
UNDERLINED DIM NOT TO SCALE	CHECKED BY
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED	ENGR APPROVAL

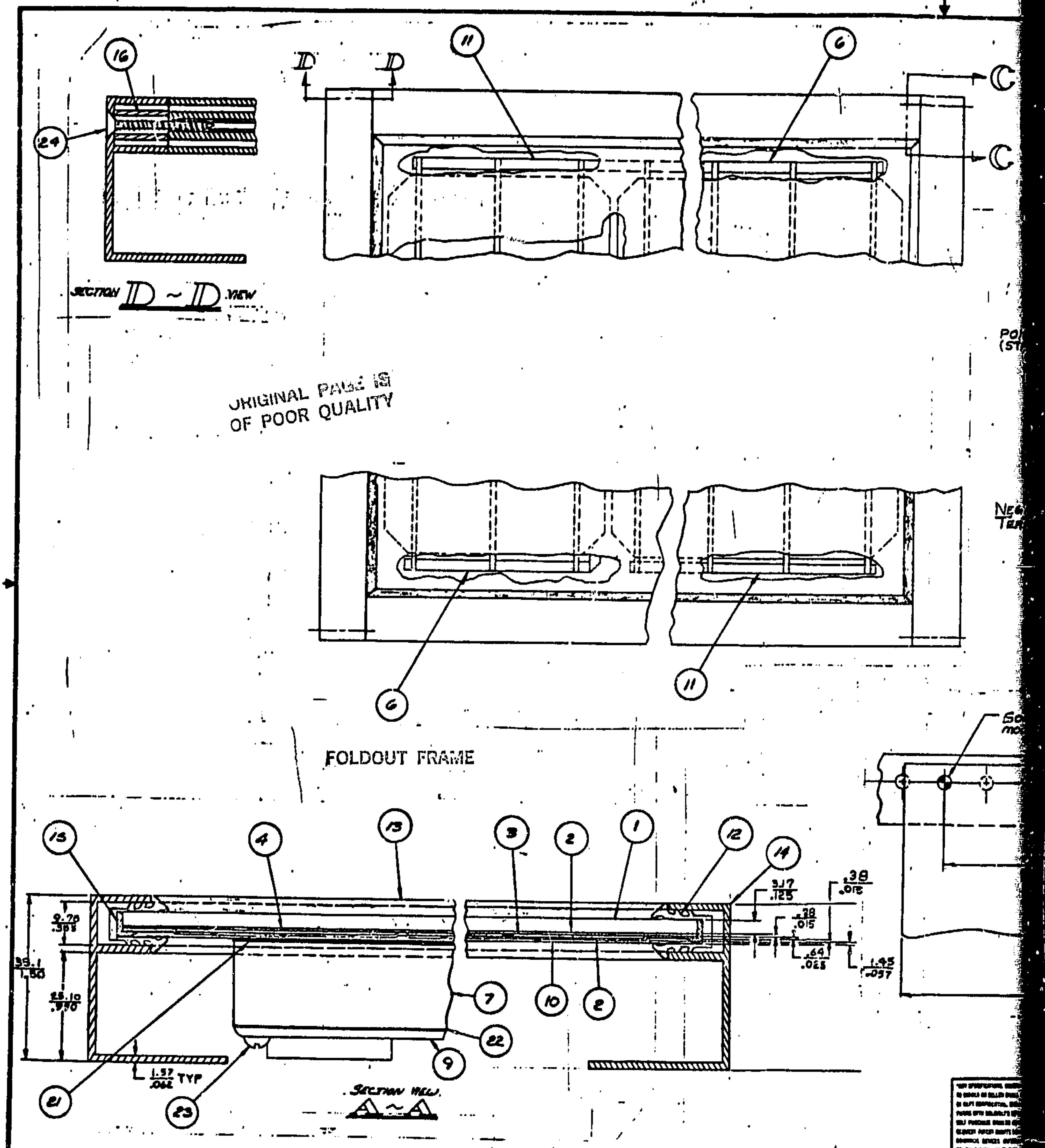
SOLAVOLT INTERNATIONAL Silicon Division

TITLE: MSP43E40B

INTERFACE CONTROL DRAWING

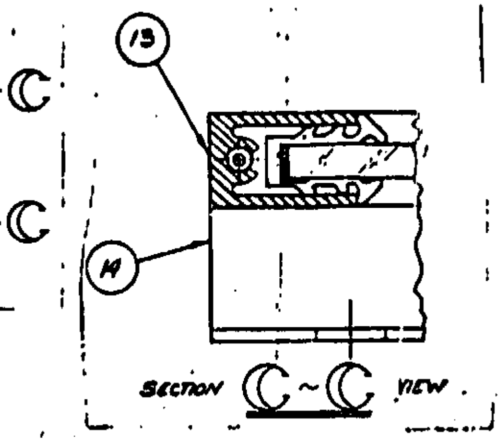
SIZE D | DRAWING NO. 01DSB21995B | SCALE 1/2 | WEIGHT | SHEET 1 OF 2

USED ON	NO. REQ'D/ASSY
APPLICATION	



SECTION D ~ D VIEW
SECTION VIEW A ~ A
1.57 .062 TYP
3.17 .125
.38 .015
.64 .025
1.45 .057
38.1 1.50

REVISIONS						
REV.	ECO NO.	CHANGE	DATE	BY	ENGR	



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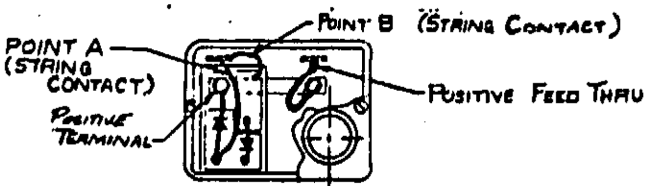
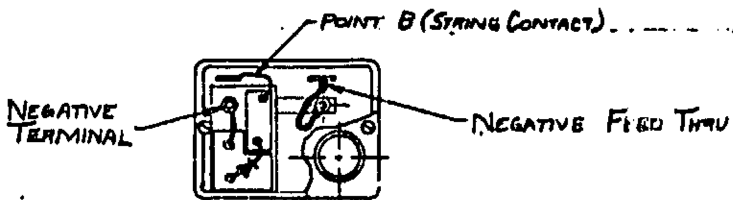
DET	REQ'D	REV	PART NO	DESCRIPTION
37	3	K	48A560131	MR750 RECTIFIER
36	1	O	30ASB21940B001	JUMPER WIRE
35	1	O	30CSB16170B003	CELL STRING BUS WIRE 5"
34	2	O	30CSB16170B002	CELL STRING BUS WIRE 49"
33	3	O	37CSB16172B002	TEFLON INSUL SLEEVING
32	2	O	84DSB11913B001	PCB - J - BOX
31	A/R	O	11ASB21309B001	ALUM, SILICONE SEALANT
30	1	O	41ASB21318B001	LABEL, SOLAVOLT LOGO
29	1	O	28CSB11834B001	BUSS BAR (POS.)
28	1	O	28CSB11834B002	BUSS BAR (NEG.)
27	1	O	41ASB21198B001	LABEL, WARNING. 3 LANGUAGE
26	1	O	02ASB21284B001	NUT GROUND LUG, SS
25	1	A	08ASB01496B002	SCREW, GROUND LUG, SS
24	4	A	08ASB08361B001	SHEET METAL SCREW #6
23	4	A	03ASB01996B001	SCREW, JUNCTION BOX
22	2	B	32DSB01993B002	GASKET JUNCTION BOX
21	A/R	B	11ASB08308B001	ADHESIVE
20	8	C	02CSB00215A001	NUT, HEX 10-24
19	5	B	04CSB03220A001	WASHER, LOCK # 10
18	8	C	04CSB00221A001	WASHER, FLAT # 10
17	1	O	41ASB21311B001	LABEL, PART #, SERIAL #
16	4	B	43ASB10600B001	SPACER CORNER
15	A/R	A	51CSB08857B001	TAPE, BUTL. SEALANT
14	2	F	07DSB08859B001	RAIL, SIDE
13	2	B	15CSB08873B001	CAP, END
12	1	B	32CSB08855B001	SEALING GASKET
11	2	B	28CSB00898B001	CONNECTOR, BUSS
10	A/R	E	11ASB00093B004	TEDLAR, ALUMINIZED (PVF)
9	2	F	18DSB00304B005	COVER, JUNCTION BOX
8	1	J	18DSB00302B004	JUNCTION BOX (NEG.)
7	1	J	18DSB00302B003	JUNCTION BOX (POS.)
6	2	B	10CSB04131B001	FEED THRU, FORMED
5	2	O	29CSB06772B001	TERMINAL, RING TONGUE
4	A/R	C	10CSB00296B001	RIBBON, SOLDER
3	38	H	60ASB02151B005	SOLAR CELL
2	A/R	B	11ASB00292B001	POLYVINAL BUTYRL (PVB)
1	1	G	61DSB98881A005	GLASS

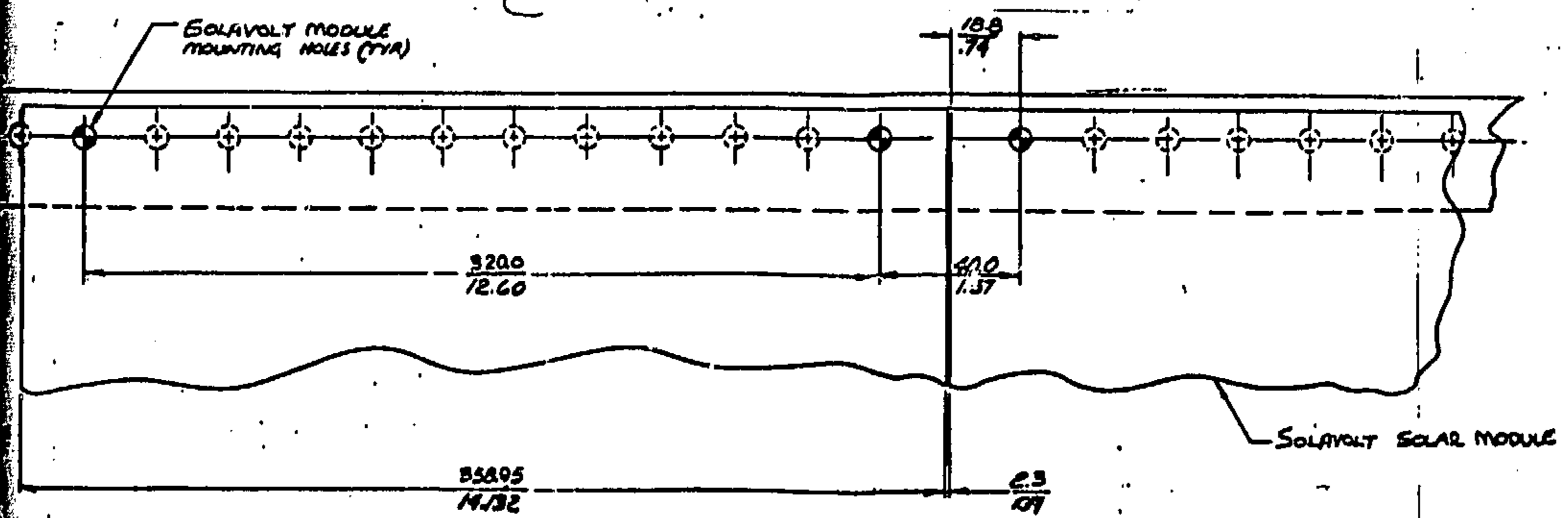


DET 'A' POSITIVE JUNCTION BOX



DET 'B' NEGATIVE JUNCTION BOX

FOLDOUT FRAME



UNLESS OTHERWISE SPECIFIED: TOLERANCES:
INCHES .XX = .XXX =
MILLIMETERS .X = .XX =
ANGULAR =
RMS ALL MACHINED SURFACES
FEATURE CONTROL SYMBOLS PER ANSI Y14.5.
BREAK ALL SHARP EDGES AND CORNERS, REMOVE BURRS.
UNDERLINED DIM NOT TO SCALE
THIRD ANGLE ORTHOGRAPHIC PROJECTION IS USED.

USED ON	NO. REQ'D/ASSY
APPLICATION	

MATERIAL	SOLAVOLT Silicon Division
QTY REQ'D	TITLE: MSP43E40B Interface Control Drawing
APPLIED FINISH	
DRAWN BY / DATE	
CHECKED BY / DATE	SIZE D — 012SE21995E — DRAWING NO.
ENGR APPROVAL / DATE	SCALE — WEIGHT — SHEET 2 OF 2

DWG. NO. 01ASB00829B

NEXT ASSEMBLY	USED ON	LTR	REVISIONS
		T	See sheet 6 for revision details

1/ NOTE: Revision of assm. 01ASB00829B010 will require update to interface control drawing 01DSB21995B.

PROD. GROUP 70ASB00828B	SEE SHEET 3 FOR DRAWINGS:
PACKAGE 01CSB21995B	SOLAVOLT INTERNATIONAL Silicon Division Post Office Box 2934 • Phoenix Arizona 85062
INSP. PLAN	
PLT. RT. SHEET	TITLE: BILL OF MATERIALS LCM SOLAR MODULE ASSEMBLY
BILL OF MAT'L. Reference Sheet 2	
ORIGINATOR D. Longstaff — DATE 4 June 79	SIZE A — CODE NO. 04713 — DWG. NO. 01ASB00829B
DRAWN BY — DATE	
CHECKED BY J. Bernasek — DATE 20 June 79	WEIGHT — SHEET 1 of 6

PRODUCT LINES

PRODUCT LINE	SOLAR CELL NO. (DIE)	ASSEMBLY NO.	FIGURE NO.	FLOW CHART	NOTES
SOE13E	REF. SHEET 4	01ASB00829B001	1	70ASB00828B	1/4 x 33 (AL. FRAME)
SOE23E		B009			1/2 x 33 (AL. FRAME)
SOE43E		B008			1 x 33 (AL. FRAME)
SOE43G		B010		1/	1 x 33 (JPL AL. FRAME)

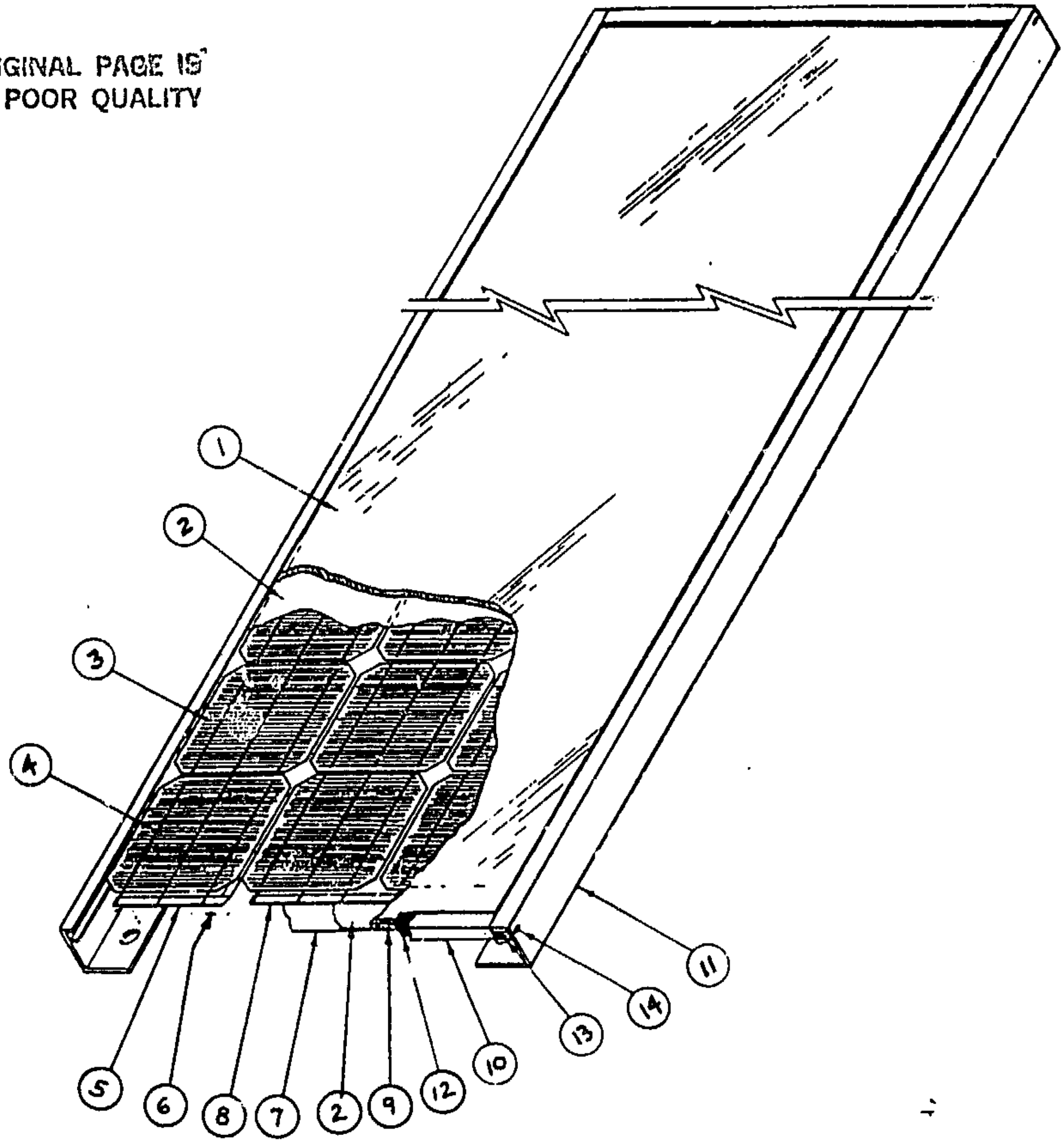
LEGEND

A = 60 FT/ST
B = 18.5 FT/ST
C = 0.5 OZ/ST
D
E = 18.25 FT^2/ST
F = 5.49 FT^2/ST
G = 4.6 FT^2/ST
H = 1.4 FT^2/ST
J = 10 FT/ST
K = 2.4 FT^2/ST

L = 9.4 FT^2/ST
M = 40 FT/ST
N
P
R
S = 4.5 IN/ST
T = 2.3 FT/ST
U
V = 5 FT/ST
W = 7 FT/ST

Y = 2 FT/ST

FIGURE #1



LINE NO	ASSY DWG CODE	PART NUMBER	DESCRIPTION	PART NO AND QUANTITY REQUIRED 1/			
		01ASB00829B	ASSEMBLY	008	009	010	011
002	1	61DSB98881A005	GLASS (FULL)	1		1	
004		A006	GLASS (1/2)		1		
006		A009	GLASS (1/4)				1
008	2	11ASB00292B001	POLYVINAL BUTYRL (PVB)	E	L	E	F
010	3	60ASB02151B005	SOLAR CELL (FULL) (STD)	33		33	
		B006	(ALT)	33		33	
		B007	(ALT)	33		33	
016		60ASB03073B005	SOLAR CELL (1/2) (STD)		33		
		B006	(ALT)		33		
		B007	(ALT)		33		
022		60ASB03366B005	SOLAR CELL (1/4) (STD)				33
		B006	(ALT)				33
		B007	(ALT)				33
028	4	10CSB00296B001	SOLDER RIBBON	A	M	A	B
030	5/8	10CSB04096B001	SOLDER RIBBON (FEED-THRU & BUSS)	T	T		T
031		*10CSB04131B001	SOLDER RIBBON (FORMED FEED-THRU)			2	
038	6	15DSB00302B003	JUNCTION BOX +	1	1	1	1
040		B004	JUNCTION BOX -	1	1	1	
042	6A	15DSB00304B005	JUNCTION BOX COVER (STD)	2	2	2	
		B004	(ALT)	2	2	2	
		B003	(ALT)	2	2	2	
048		B007	JUNCTION BOX COVER				1
050	7	11ASB00293B004	ALUMINIZED TEDLAR (PVF) (STD)	G	K	G	H
052		28CSB11334B001	BUSS BAR POSITIVE			1	
		B002	BUSS BAR NEGATIVE			1	
054	8	28CSB00298B001	BUSS CONNECTOR			2	
055	9	51CSB08857B001	SEALANT TAPE (PRIMARY)	J	W	J	V

NOTE: ASSEMBLIES CONTINUED ON PAGE 5

SOLAVOLT.
INTERNATIONAL
SILICON DIVISION

TITLE:	ISSUE	DOC. NO.
LCM SOLAR MODULE ASSEMBLY	1	01ASB00829B
		PAGE 5 OF 6

LINE NO	ASSY DWG CODE	PART NUMBER	DESCRIPTION	PART NO AND QUANTITY REQUIRED 1/			
		01ASB00829B	ASSEMBLY (CONTINUED)	008	009	010	011
058	10	15CSB08873B001	END CAP	2	2	2	2
060	11	07DSB08859B001	SIDE RAIL (FULL)	2			
062		B002	(FULL-JPL)			2	
064		B003	(1/2)		2		
066		B004	(1/4)				2
068	12	32CSB08855B001	SEALING GASKET (SECONDARY)	1		1	
069		B002	" " "		1		
070		B003	" " "				1
071		*32DSB01993B002	GASKET, J-BOX			2	
072	13	11ASB21309B001	ALUMINUM SILICONE SEALANT	C	C	C	C
074	14	03ASB08861B001	SCREW, SHEET METAL #6	4	4	4	4
076		03ASB01996B002	SCREW, SS 10-32 3/4" Tg GND LUG			1	
078		B001	SCREW, J-BOX	4	4	4	2
082		04CSB80221A001	FLAT WASHER #10	4	4	8	4
084		04CSB80220A001	LOCK WASHER #10	4	4	5	4
086		02ASB21284B001	HEX NUT SS 10-32 GND LUG			1	
088		02CSB80218A001	HEX NUT 10-24	4	4	8	4
090		29CSB06772B001	RING TONGUE TERMINAL	2	2	2	1
092		B002	" " "				1
094		11ASB02305B001	ADHESIVE	2	2	2	1
096		43ASB10600B001	CORNER SPACER	4	4	4	4
098		41ASB21313B001	LABEL, SOLAVOLT LOGO	1	1	1	1
099		41ASB21198B001	LABEL, 3 LANGUAGE WARNING	1	1	1	1
100		41ASB21311B001	LABEL, PART #/SERIAL #	1	1	1	1
102		37ASB12231B001	TEFLON SLEEVING				S
103		*37CSB16172B002	TEFLON INSULATING SLEEVING			3	
104		30ASB12229B001	MAGNET WIRE				Y
106		*30CSB16170B002	CELL STRING BUSS WIRE 49"			2	
108		* B003	" " " " 5"			1	
110		*30ASB21940B001	JUMPER WIRE			1	
112		*84DSB11913B001	PCB J-BOX			2	
114		* 91RL613M	MR750 RECTIFIER			3	

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REVISION SHEET

ISSUE	DESCRIPTION OF REVISION	SPECIFICATION COORDINATOR & DATE
P	SHT. 2 REVISED LEGEND ITEMS G, H, K. SHT. 5 ADDED LINE 89 - 43CSB10600B001. LINE 014. 11ASB00293B002 CHANGED FROM STD. PT. TO ALT. PT. ADDED LINE 014, 11ASB00293B004 AS STD. PT. LINE 040, 51ASB07483B001: DELETED QTY FROM KITS 008, 009, 010. Req. by D. Golsner	D.W.S. 9/29/82
R	DOCUMENT EXTENSIVELY REVISED. DELETED ASSM NOS. B001, B004, B005, B006, B007. Req. by Dwight Doss.	D.W.S. 6 DEC 82
S	ASSM 010 EXTENSIVELY REVISED. SEE OBSOLETE ISSUE FOR DETAILS. 01CSB21995B IS REFERENCED. Req. by D. Doss	D.W.S.
T	Note 1: Ref Dwg was 01CSB21995B. Requested by B. Larson	D.W.S. 24 Mar. 83

SECTION 3

SOLAR CELL MODULE

FEATURES/DESCRIPTION

MSP43E40B

PHYSICAL CHARACTERISTICS

DIMENSIONS: - Length: 1217mm (47.90")
Width: 358mm (14.1")
Height: 38mm (1.5")
Weight: 5.7Kg (12.5 lbs.)

CONSTRUCTION:

† Cover Glass:	125 mils thick tempered (Solatex)
† Pottant:	Polyvinyl butyl (Saflex)
† Back Skin:	Al-polyvinyl fluoride (Tedlar) laminant
† Edge Sealant:	Cross-linked polyisobutylene tape
† Edge Gasket:	Seamless polyvinyl chloride
† Frame:	Aluminum alloy type 6063-T5 Anodized per Alcoa 204R1
† J-Box:	Glass filled polycarbonate
† Binding Posts:	Nickel plated steel
† Interconnect (Cell):	Three copper ribbons, continuously bonded across top and bottom of cells
† Bypass Diode:	Motorola MR750 rectifier

OPERATING CONDITIONS:

† Ambient Temperature:	40C to 60C
† Wind:	
Constant velocity:	160Km/Hr (100 mph) max
Gust velocity:	200Km/Hr (125 mph) max

MECHANICAL:

† Snow Loading:	290 Kg/m^2 (60 psf) max
† Shock:	.4M (15 in) drop per MIL-STD-810B

SECTION 4

MUDULE DESIGN RATIONAL

4. MODULE DESIGN RATIONAL

Solar Cell Module: A Product Description

The Solavolt solar module design, and associated manufacturing approach, represent a balance between customer and manufacturing concerns. The module has been electrically configured to serve remote and intermediate-load applications in 12 volt multiples, with a typical module able to deliver 38 watts at 1-sun (100 mW/cm^2 and 25°C).

The module's physical dimensions are 47.9 inches (1.22M) by 14.1 inches (.358M) and is depicted in Figure 1.

Solar Cell Design and Fabrication

Silicon solar cells to be incorporated into the production modules are constructed on 100 x 100mm p-type silicon wafers, approximately 0.015" thick. The cells have texture etched, non-reflective front surfaces with very shallow, planar pn junctions. Silicon nitride is used as both an anti-reflection coating, and as a surface passivation. The silicon nitride layer is resistant to moisture and contaminants, and is extremely adherent to the solar cell surface. Back surface doping enhancement is utilized to form a back surface field and to ensure a low resistance ohmic contact.

The nickel metallization system is plated on both front and back surfaces and sintered to produce contacts with low contact resistance and high adhesion to the silicon surface. Low cell series resistance is then achieved through solder coating of the metal contacts.

The metallization pattern has three contact busses which pass over the complete length of the cell. Orthogonal metal collector fingers minimize cell internal voltage losses (and hence maximize available output power). This design provides an ideal contact geometry for mechanizing across-the-cell ribbon connections, and, in addition, provides a high degree of contact redundancy.

Electrical Interconnection

The consistent, reliable electrical interconnection of individual solar cells to provide desired array electrical outputs is a primary consideration in the design and fabrication of solar modules. The approach which Solavolt has pursued to achieve this key function is based on the across-the-cell ribbon contacting and is described in the following sections.

Cell-To-Cell Interconnection

The cell-to-cell electrical interconnection is accomplished via three redundant solder coated copper ribbons. This approach was selected on the basis of three predominant advantages:

1) The minimization of power loss with cracked cells.

2) Maximize active cell area.

3) Maximize Reliability

A copper ribbon with a cross section of 3 mils x 78 mils has been selected for the cell-to-cell interconnect. This ribbon contributes less than one millivolt drop per solar cell at the peak current rating and is rippled to reduce any stresses at the ribbon-cell contact interfaces.

Internal bussing for the electrical feedthroughs is obtained via tinned copper busses at either end of the series string, which protrude through the backskin. The interconnect-to-feedthrough electrical connection is accomplished by fastening the electrical feedthrough to the Junction Box binding post. The Junction Box binding posts are of nickel plated copper to enhance their environmental resistance.

Circuit-Case Electrical Isolation

Circuit-to-case electrical isolation is provided by a dielectric layer (PVB & Tedlar) between the circuit and aluminum foil barrier on the back side of the module. An outer layer of Tedlar acts as an additional dielectric layer, as well as the weatherable outer surface. Slots are formed in the aluminum layer to correspond to the feedthrough locations.

Isolation is provided between the glass cell laminate structure by an edge seal consisting of a butyl tape and a seamless polymer gasket which supports and cushions the laminate assembly in the aluminum frame. A 10-32 stud is affixed to the side rail to provide a convenient case ground. Two alternate locations are provided for the ground stud.

Enclosure

The enclosure developed to encapsulate the solar cells and their interconnect system consists of a glass cover plate sandwiched to a multilayer backskin by polyvinyl butyl. This void-free structure is supported at its edges by an anodized aluminum bezel to which it is sealed by a butyl tape and a seamless polymer gasket. The cover glass is of low iron content (less than .1%), has been tempered and edge seamed to increase both thermal shock and impact resistance. The aluminum components are architecturally anodized

which combines good structural ability and excellent corrosion resistance in terrestrial environments.

Thermal Considerations

The solar cell modules have a reasonable propensity for passive heat dissipation, which results in a low temperature rise of the solar cells over the prevailing ambient temperature. The high cell packing density (76%) provides for uniform heat generation (absorption) within the module, helping to maintain a uniform temperature and assisting in heat removal to the surroundings by convection and radiation. Initial NOCT measurements have yielded values of approximately 47°C at 80 mW/cm^2 and 56°C at 100 mW/cm^2.

Environmental Sealing Considerations

The primary seals of the module are at the perimeter interface and electrical feedthrough locations, since the backskin and glass components will constitute impenetrable barriers. The peripheral interface deserves particular attention in that it must be a flexible barrier to accommodate cyclic thermally induced strains that are of the order of tens of thousandths of an inch. The electrical feedthrough interfaces are of similar stature. The approach which has been developed for the Solavolt solar module is to provide a primary seal at these interfaces and to further guard against metallization and optical failures by 1) providing a secondary distributed sealant throughout the internal portions of the module, i.e., PVB, and 2) utilizing a self-passivating interconnect metal system.

The perimeter seals are effectively accomplished by a combination of frame design and sealant selection. The primary sealant is a butyl rubber tape which is run along the entire edge of the module. The sealant is placed in intimate contact with the inner PVB (pottant), which acts as the secondary seal.

A secondary perimeter seal is effected by a seamless polymer gasket which is placed around the glass laminate assembly before the aluminum frame members are attached.

Design Innovations

The Solavolt solar module and associated manufacturing processes have been designed to achieve long user life compatible with a minimum manufacturing cost. The module encapsulation system is based on automobile windshields, but modified as necessary to align with the realities of solar cell electrical subassemblies.

The interconnection of individual cells in the "across-the-cell" manner provides a significant advance over previous designs in the areas of 1) manufacturing inspection requirements and 2) safeguarding against cracked cell power losses in the field.

The Solavolt solar module packaging density has been significantly improved via advances in the cell substrate processing areas, which allow for the cost effective "squaring" of cells.

Electrical & Mechanical Design Requirements

The Solavolt module has been qualified to the Block IV design requirements and has been tested to the expanded criteria of Block V as outlined in JPL Document 5101-161. The module satisfies all the requirements of isolation, grounding, and cell string redundancy. To ensure the hot spot endurance requirements are satisfied, the Block V module incorporates the bypass diodes such that each 11-cell string is bypassed. This approach limits the reverse voltage to which an individual cell may be subjected to less than 6.0 volts which is less than the reverse breakdown of the typical Solavolt cell.

The expanded mechanical criteria of Block V has been satisfied by changing the module frame material to anodized aluminum, by adding a gasket around the perimeter of the glass cell laminate assembly, and by making design improvements to the module Junction Boxes.

Solavolt Block V modules are interchangeable with Block IV modules and all the criteria required for Block V qualification are satisfied with the Solavolt MSP43E40B module.

Manufacturing Sequence

The manufacturing sequence consists of interconnecting the solar cells electrically in series into eleven cell strings through the use of solder coated copper ribbons which are reflowed onto the cells at a reflow station. The cell strings are connected to each other through the use of solder coated copper bus bars and the three ends of the 11 cell strings are brought into the Junction Box by use of a solder coated feedthrough.

The solder cell-interconnect assembly is sandwiched between two layers of polyvinyl butyl and laminated to a tempered glass superstrate and a tedlar-aluminum-tedlar backskin in a heat vacuum laminating operation. After lamination, the glass cell laminate assembly is edge sealed with butyl tape and mounted into anodized aluminum side and end rails. The laminate assembly is held in place in the aluminum frame members by a seamless polyvinyl-choloride gasket which serves as a cushion and an additional edge seal.

Two Junction Boxes are attached to the laminate assembly where the positive and negative feedthroughs are brought through the backskin. The Junction Boxes are attached using epoxy which not only attaches the box but seals the area where the feedthrough comes through the backskin and enters the module. Each Junction Box contains a small printed circuit board upon which the bypass

diodes are mounted. The printed circuit board acts as a heat sink for the diodes when they may be conducting and allows easy accessibility to the diodes in the event that replacement is ever required.

The final manufacturing operation involves those of electrical test, QA visual inspection and module labeling. The testing is performed on a Spectrolab Large Area Pulsed Solar Simulator.

SECTION 5

PERFORMANCE DATA

5. PERFORMANCE DATA

The following values for nominal electrical performance are the average for the 20 modules built for this contract (10 Group I and 10 Group II modules).

- NOCT - 56°C (100 mW/cm^2)
  - 49°C (80 mW/cm^2)

- Packing Factor - 0.76

- Nominal Electrical Performance (AM 1.5)

Parameter	100 Mw/cm^2 25°	100 mW/cm^2 NOCT	80 mW/cm^2 NOCT
Max Power (Watts)	38.7	34.3	28.0
Max Power Voltage (Volts)	16.0	14.5	14.8
Max Power Current (Amps)	2.42	2.37	1.89
Voc (Volts)	19.3	17.8	18.1
Isc (Amps)	2.63	2.66	2.12
Module Efficiency	9.1	8.1	6.6
Encapsulated Cell Eff	12.0	10.7	8.7
Fill Factor	0.76	0.73	0.73
Minimum Isolation Voltage (Volts)	3000	3000	3000

- Module Temperature Coefficients

  V/ T (Volts/°C) = -0.078

  I/ T (Amps/°C) = +0.0011

SECTION 6

BLOCK V QUALIFICATION TESTS

6. BLOCK V QUALIFICATION TESTS

Conditions

In order for a module type to pass the Block V requirements, samples must pass the following environmental exposures.

- Breakdown voltage from terminals to frame must exceed 3000 Vdc

- Module shall be capable of withstanding the JPL hot-spot endurance test

- Module must withstand the following environmental exposures:

  - 200 thermal cycles between -40°C and +90°C
  - 10 cycles of 90% relative humidity between -40°C and +85°C
  - 10,000 cycles of mechanical cycles pressure, simulating wind and other loads of +/- 50 lb/ft^2
  - Twisted mounting surface of 1/4 in/ft
  - Impact of simulated hailstones of 1.0 in diameter traveling at a speed of 52 mph

Results

Seven of the Group I modules, 5068, 5070, 5071, 5072, 5073, 5076, and 5077 were subjected to various environmental exposures at JPL. Modules 5069, 5074, and 5075 were set aside as control modules. No module suffered unsatisfactory electrical degradation and the exposure results are as follows:

Mechanical Integrity

Four modules, 5072, 5073, 5076, and 5077 were subjected to 10,000 cycles of the mechanical integrity exposure. While the results on modules 5072 and 5073 were satisfactory, on modules 5076 and 5077 the Junction Boxes loosened from the module backskin and there was cracking of the plastic around the J-Box cover screw inserts.

Hot Spot Endurance

Module 5068 was subjected to the Hot Spot endurance test with the result that there was some wrinkling of the Tedlar backskin and a minor discoloration behind three (3) of the tested cells. The power degradation of the module through this exposure was 2.0 percent.

Temperature Cycling

Six modules were subjected to temperature cycling - modules 5070 and 5071 were exposed to 200 cycles while module 5072, 5073, 5076 and 5077 were subjected to 50 cycles as a part of other exposures. The results of this testing is summarized as follows:

Module	50 Cycles	200 Cycles
5070	Satisfactory	Tedlar splitting and peeling near Junction Box
5071	Satisfactory	Delamination between cells in one location
5072	Plastic at J-Box Cover - Screw Inserts cracked	------
5073	Plastic at J-Box Cover - Screw Inserts Cracked	------
5076	Satisfactory	------
5077	Satisfactory	------

Humidity Freeze Cycles

Four modules, 5072, 5073, 5076 and 5077 were subjected to 10 cycles of humidity freeze with the results on all four modules being satisfactory through this environmental exposure.

It should be noted that at the time this report was written the Group II modules had not completed testing. The results of the Group II modules will be reported in an appendix to this final report.

SECTION 7

PROBLEM AREAS AND CORRECTIONS

7. PROBLEMS AREAS AND CORRECTIONS

The main areas of concern of the Group I modules are those surrounding the attachment of the Junction Box to the backskin and the facts that on several modules the plastic around the Junction Box cover inserts cracked. Each of these items will be considered separately.

Plastic Around Inserts

The problem of the plastic cracking around the Junction Box cover inserts on Modules 5072, 5073, 5076 and 5077 has also been seen in Solavolt module testing. Since the Group I modules were fabricated, two (2) design changes have been made to the Junction Box in the areas of the insert and the basic box material.

Inserts

The Junction Boxes on the Group I modules used an insert made of cadmium plated steel requiring a hole diameter of 250 mils. This insert was replaced by a brass insert requiring a hole diameter of only 200 mils. The effect of going to the new insert was to increase the wall thickness around the insert by 25 mils while improving the corrosion characteristics of the insert itself. This change was incorporated in Revision H of the Junction Box Spec dated July 8, 1982.

Composition of Junction Box Material

The composition of the Junction Box material was changed from 30% glass filled to 10% glass filled in Revision J of the Spec dated November 9, 1982. This change was made to make the Junction Box less brittle and further prevent problems such as the material cracking around the cover inserts.

The test results on modules having Junction Boxes incorporating these changes has been favorable and it appears that 200 or more cycles of temperature cycling will cause no problems with the plastic around the cover inserts.

Junction Box Attachment

After the JPL test results of the Group I modules were made known to Solavolt, a check was made of the procedures and materials used in attaching the Junction Box to the module. It was discovered that manufacturing personnel were using epoxy kits which were many months out of date (which was also the case when the Group I modules were fabricated).

The question of the backskin tearing in the region of the Junction Box was traced to the size of the epoxy fillet under the Junction Box. Per JPL recommendations under the Block IV program, the Junction Box was attached to the backskin with a generous amount of epoxy which yielded a large fillet of epoxy around the bottom of the Junction Box. While this fillet ensured that the area around

the feedthrough would be well sealed, there were some questions as to whether this fillet of relatively hard epoxy was contributing to the backskin tearing through temperature cycling such as was the case on module 5070. In fact after a series of experiments it was determined that the large epoxy fillet was the cause of the backskin tearing. Manufacturing process changes were made to reduce the fillet to the minimum possible size while still ensuring the perimeter of the Junction Box would be sealed.

SECTION 8

CONCLUSION

8. CONCLUSION

The test results indicate that the Solavolt MSP43E40B module does satisfy the design criteria and test requirements of the JPL Block V qualification specification for intermediate load modules as outlined in JPL 5010-161 dated February 20, 1981.

While some minor problems were identified in the environmental testing of the Group I modules, design changes were made to overcome these deficiencies which enabled the Group II modules to pass the qualification tests as outlined in Appendix A of this report.

APPENDIX A

QUALIFICATION TEST RESULTS OF THE GROUP II MODULES

APPENDIX A

QUALIFICATION TEST RESULTS OF THE GROUP II MODULES

Results

Six of the Group II modules, 7577 - 7582, were subjected to environmental exposures of temperature cycle, humidity freeze and mechanical integrity at JPL. Modules 7583 - 7586 were set aside as control modules. No module exhibited unsatisfactory electrical degradation and the exposure results are as follows:

Mechanical Integrity

Modules 7579, 7580, 7581 and 7582 were subjected to 10,000 cycles of cyclic loading exposure. All of these modules passed this exposure satisfactorily with no detectable problems.

Temperature Cycling

Six modules were subjected to temperature cycling - modules 7577 and 7578 were exposed to 200 cycles while modules 7579 - 7582 were exposed to 50 cycles. The results of this testing is summarized as follows:

Module	50 Cycles	200 Cycles
7577	Mild backskin wrinkling Some edge sealant run	Negative J-Box loosened
7578	Mild backskin wrinkling Some edge sealant run	Negative J-Box loosened
7579	Mild backskin wrinkling	-------
7580	Mild backskin wrinkling	-------
7581	Mild backskin wrinkling	-------
7582	Mild backskin wrinkling	-------

Humidity Freeze

Modules 7579 - 7582 were subjected to 10 cycles of humidity freeze with unsatisfactory results in that both junction boxes on each of the four modules loosened during the exposure. The looseness was a result of a clean separation between the J-Box and the epoxy used to attach the box to the backskin.

To investigate this J-Box attachment problem, modules 7579 and 7580 were returned to Solavolt for evaluation and failure analysis. This analysis indicated that the Junction Boxes had not been properly cleaned prior to their attachment to the module.

New controls were instituted on the J-Box handling, cleaning and mounting procedures and modules 7579 and 7580 were replaced with modules 8508 and 8510 which were fabricated using the new procedures. These two new modules were sent to JPL and subjected to 50 cycles of thermal cycle and 10 cycles of humidity freeze where they satisfactorily passed both exposures.